

CORPS OF ENGINEERS, U. S. ARMY

**STUDY OF BUTTERFLY VALVES FOR
PEARL RIVER LOCKS**

MODEL INVESTIGATION



TECHNICAL MEMORANDUM NO. 2-313

**WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI**

ARMY-WES VICKSBURG, MISS.

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Introduction

1. Three locks are authorized for construction on a canal paralleling the Pearl River immediately south of Bogalusa, in southeastern Louisiana. Each lock is to be 65 ft wide by 310 ft long and is to have a minimum depth of 10 ft over the sills. Lifts will vary from 5 to 28 ft at Lock 1, from 13 to 22 ft at Lock 2, and from 11 to 17 ft at Lock 3. Filling of these locks will be accomplished by loop culverts around the miter gates, flow through which will be controlled by three butterfly valves arranged as shown on plate 1.

2. One of the three locks proposed, Lock 1, has been constructed and is now in operation. Control valves for this lock are at present operated manually; however, plans are being made to mechanize these valves and to provide automatic operation for the valves on the other two locks. Prior to designing operating machinery the Mobile District conducted a series of tests at Lock 1 to determine the hydraulic forces acting on the butterfly valves. A head differential of 11.1 ft obtained during the period in which the tests were conducted. With the three valves connected to the same driving mechanism, the torque resulting from hydraulic forces amounted to a maximum of 129 in.-kips and tended to close the system. A closing torque of 73 in.-kips was measured on valve A (plate 1) when operated alone. Personnel of the

Mobile District were of the opinion that such torque values were excessive and requested that a short series of model tests be conducted to determine if hydraulic forces acting on the valves could be reduced by addition of some system of deflectors or baffle plates. Actual authorization for the tests was contained in a letter dated 25 May 1949, to the Waterways Experiment Station, subject: "Model Study of Lock Culvert Valves for Pearl River Locks." Since time was the essence, the tests were confined to eight combinations of deflectors and baffle plates proposed by the Mobile District Office. Tests were conducted during the period June-August 1949.

3. A 1:8-scale model reproduced the culvert entrance, the valve section, the right-angle elbow immediately below the valve section, and about 50 ft of the culvert. The culvert was constructed of transparent plexiglass, the valves were made of brass, and the valve shafts of stainless steel. The valve shafts were mounted on stainless steel bearings, thereby reducing friction to a minimum. Mounted to each valve shaft was a horizontal arm of known length to which was attached precise spring scales for the measurement of forces acting on the valves. These arms were so linked together that the resulting force could be measured individually for each valve or for any combination of valves.

Tests and Results

4. Tests were conducted on the valves as installed in the existing lock and on seven modifications thereof. Data collected

are tabulated in tables 1-3 and are summarized in the plots on plates 2-12. Since discharge through the valves was not a critical factor, provisions were not made to measure discharge for all tests. However, facilities in which the model was installed permitted discharges up to about 700 cfs (prototype), which constituted about 0.6 of the maximum discharge to be measured accurately. It was noted that every arrangement employed to reduce torque (deflectors or baffle plates) caused discharge capacities to be reduced.

5. Initial tests on the model were conducted under a head of 11.1 ft in order to provide a direct comparison with data obtained on the prototype locks. Various combinations of valves operating and openings were investigated. It was found that the characteristics of the torque curves obtained from the model and prototype were generally similar, although the maximum torque measured was usually greater with the model valves than that with the prototype (plates 2 and 3 and table 1). Since it was necessary to adjust the prototype measurements to compensate for frictional effects, the prototype torque values presented were considered approximate.

6. In tests conducted for comparison of the proposed schemes of improvement, a head differential of 16.75 ft was used and, although multiple valve operation was at equal openings, individual measurements of the force tending to close each valve were made. The product of these forces and the moment arm (4 ft) gave the torque values presented in the tables and plotted on the plates. For a head differential of 16.75 ft and the original-design valve a maximum torque of about

98 in.-kips was measured on the trunnion of each of the three valves. The maximum torque was measured with the valves 1/2 open (plate 4). One deflector was added to the downstream side of the valve leaf that moves upstream as a valve is opened (test 2). It was found that this deflector reduced maximum torque to about 86 in.-kips on valve A, and 77 in.-kips on valves B and C (plate 5). Addition of a second deflector on the downstream side of the valve leaf that moves upstream as the valve is opened (test 3) further reduced maximum torque to about 54 in.-kips on valve A, 51 in.-kips on valve B, and 56 in.-kips on valve C (plate 6). In combination with the two deflectors previously installed, one deflector was added to the upstream side of the valve leaf that moves downstream when the valve is opened (test 4). For this arrangement maximum torque measured on the valves was as follows: valves A and C, 37 in.-kips and valve B, 28 in.-kips (plate 7). For test 5 the deflector was removed from the leaf of the valve that moves downstream as the valve is opened, and a plate was installed on the valve as shown on plate 8. This arrangement caused an increase in torque to about 79 in.-kips on valve A, 57 in. kips on valve B, and 59 in.-kips on valve C. Test 6, data for which are presented on plate 9, involved the use of three deflectors in similar positions to those used in test 4, but with longer arms. This arrangement produced maximum torque of about 22 in.-kips on valves A and C, and 19 in.-kips on valve B. Since test 6 produced torque values considered to be well within those allowable, this arrangement was tested under a head

differential of 28 ft, the maximum to be expected at any of the locks. Torque measured with a 28-ft head differential amounted to a maximum of 31 in.-kips on valves A and B, and 38.5 in.-kips on valve C (plate 10). Comparison of torque values obtained for the two conditions of head differential indicate in general that the torque on the valves varied directly as the head differential across the valves. For test 7 the arrangement of deflectors used in test 4 was supplemented by the addition of plates on both the upstream and downstream leaves of the valve (plate 11). This arrangement caused a slight reduction in torque over that obtained in test 4 (compare plates 11 and 7). The scheme investigated as test 8 consisted of the three deflectors used in test 6 plus an additional deflector on the upstream side of the leaf of the valve that moves downstream as the valve is opened. This arrangement produced greater torque than did the three deflectors used in test 6 (compare plates 12 and 9).

7. Comparison of results of all alterations effected for the various tests indicates that the baffle arrangement designated test 6 (plates 9 and 10) provided the best torque conditions of any of the types investigated. For a head differential of 16.75 ft the maximum torque obtained for test 6 was 21.5 in.-kips whereas the maximum torque obtained with the original-design valve was 98 in.-kips. For a head differential of 28 ft the maximum torque of 38.5 in.-kips recorded during test 6 represents only about 23 per cent of the computed maximum torque that would obtain under like conditions for the original valve. The computed maximum torque (165 in.-kips) was

based on the premise mentioned in the previous paragraph that the torque varied directly as the head differential across the valves. The discharge capacity with the test 6 arrangement was only 46 per cent as much as with the original valves (test 1) when one-quarter open, and 65 per cent as much as when one-half open. Although it was not possible to obtain measurements, it is believed that the difference in discharge between the two designs would become less as the valve opening increased.

8. Measures to reduce torque effected consequent reductions in hydraulic capacities. However, low torques were considered more critical than time of filling the lock. Therefore, the type of valve investigated in test 6 is considered the best of those tested for installation in the prototype.

TABLE 1
MODEL-PROTOTYPE COMPARISON

Valves Operating	Valve Opening	Head Differential (ft)	Discharge From Model (cfs)	Total Torque on Valve Trunnions*	
				Model** (in. Kips)	Prototype (In. Kips)
A, B	1/4	11.1	268	70.8	68.4
A, B	3/8	11.1	427	95.2	----
A, B	1/2	11.1	537	92.2	82.8
A, B	5/8	11.1	611	70.6	----
A, B	3/4	11.1	643	40.0	67.2
A, B	Full	11.1	614	24.6	2.4
B, C	1/4	11.1	293	98.3	117.6
B, C	3/8	11.1	404	129.0	----
B, C	1/2	11.1	511	149.1	122.4
B, C	5/8	11.1	581	147.5	----
B, C	3/4	11.1	632	113.6	100.8
B, C	Full	11.1	620	49.2	2.4
A, B, C	1/4	11.1	400	141.3	123.6
A, B, C	3/8	11.1	584	175.1	----
A, B, C	1/2	11.1	745	175.1	128.4
A, B, C	5/8	11.1	806	135.2	----
A, B, C	3/4	11.1	852	86.0	110.4
A, B, C	Full	11.1	790	12.3	2.4
A	1/4	11.1	129	12.3	16.8
A	3/8	11.1	198	21.5	----
A	1/2	11.1	257	24.6	27.6
A	5/8	11.1	299	24.6	----
A	3/4	11.1	327	12.3	19.2
A	Full	11.1	317	15.4	0.0
C	1/4	11.1	125	40.0	46.8
C	3/8	11.1	187	61.4	----
C	1/2	11.1	240	73.7	74.4
C	5/8	11.1	275	73.7	----
C	3/4	11.1	307	66.1	73.2
C	Full	11.1	315	36.9	58.8

*Forces tended to close valves.
**All torque values are in prototype terms.

TABLE 2
HYDRAULIC TORQUE ON BUTTERFLY VALVES

Test No.	Valves Operating	Valve Opening	Headwater* (ft)	Tailwater* (ft)	Discharge (cfs)	Torque on Valve Transmissions		
						A (In. Kips)	B (In. Kips)	C (In. Kips)
1	A, B, C	1/4	23.25	Free	489	61.4	86.0	73.7
1	A, B, C	1/2	23.25	6.5	914***	98.3	98.3	98.3
1	A, B, C	3/4	23.25	6.5	1045***	86.0	43.0	33.8
1	A, B, C	Full	23.25	6.5	970***	24.6	24.6	24.6
2	A, B, C	1/4	23.25	Free	435	15.3	36.9	43.0
2	A, B, C	3/8	23.25	6.5	659	55.3	67.6	64.5
2	A, B, C	1/2	23.25	6.5	---	86.0	76.8	77.0
2	A, B, C	3/4	23.25	6.5	---	67.5	49.2	40.0
2	A, B, C	Full	23.25	6.5	---	0.0	0.0	0.0
3	A, B, C	1/4	23.25	Free	411	15.3	30.7	40.0
3	A, B, C	3/8	23.25	6.5	653	40.0	49.2	55.3
3	A, B, C	1/2	23.25	6.5	820	53.7	50.8	55.3
3	A, B, C	3/4	23.25	6.5	---	52.3	27.6	30.7
3	A, B, C	Full	23.25	6.5	---	0.0	9.3	0.0
4	A, B, C	1/4	23.25	Free	254	12.3	12.3	12.3
4	A, B, C	3/8	23.25	6.5	474	18.4	18.4	30.7
4	A, B, C	1/2	23.25	6.5	666	18.4	24.6	36.9
4	A, B, C	5/8	23.25	6.5	856	36.9	27.6	33.9
4	A, B, C	3/4	23.25	6.5	---	30.7	24.6	18.4
4	A, B, C	Full	23.25	6.5	---	12.3	6.1	6.1
5	A, B, C	1/4	23.25	Free	388	9.2	30.7	36.8
5	A, B, C	3/8	23.25	6.5	585	27.6	43.0	52.2
5	A, B, C	1/2	23.25	6.5	---	78.4	56.9	58.3
5	A, B, C	3/4	23.25	6.5	---	76.8	36.9	30.7
5	A, B, C	Full	23.25	6.5	---	24.6	6.1	6.1
6	A, B, C	1/4	23.25	Free	226	6.1	6.1	12.3
6	A, B, C	3/8	23.25	6.5	427	12.3	15.3	21.5
6	A, B, C	1/2	23.25	6.5	596	15.5	15.5	21.6
6	A, B, C	5/8	23.25	6.5	767	18.4	18.4	17.0
6	A, B, C	3/4	23.25	6.5	---	21.5	15.3	15.3
6	A, B, C	Full	23.25	6.5	---	12.3	12.3	12.3
7	A, B, C	1/4	23.25	Free	244	9.2	12.3	12.3
7	A, B, C	3/8	23.25	6.5	466	15.3	18.4	30.7
7	A, B, C	1/2	23.25	6.5	667	18.4	24.6	33.8
7	A, B, C	3/4	23.25	6.5	---	32.3	24.6	21.6
7	A, B, C	Full	23.25	6.5	---	12.3	6.1	12.3
8	A, B, C	1/4	23.25	Free	220	0.0	9.2	6.1
8	A, B, C	3/8	23.25	6.5	351	12.3	18.4	18.4
8	A, B, C	1/2	23.25	6.5	504	50.7	44.6	50.7
8	A, B, C	5/8	23.25	6.5	604	33.9	27.6	30.8
8	A, B, C	3/4	23.25	6.5	737	30.7	26.2	27.6
8	A, B, C	Full	23.25	6.5	---	24.6	6.1	0.0

*Referred to bottom of culvert at valves.

**Forces tended to close valves.

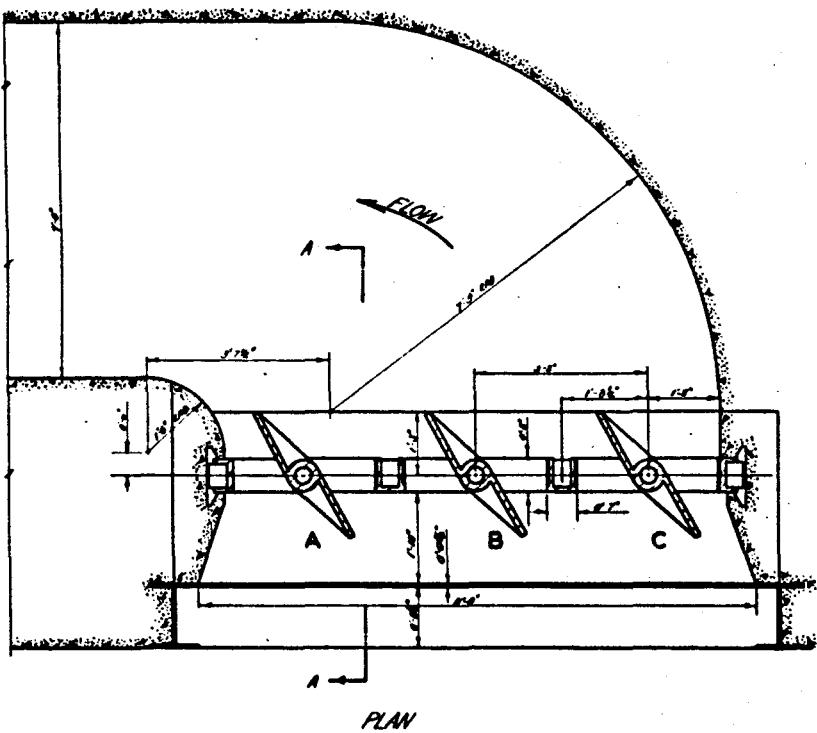
***Computed from data on table 1.

TABLE 3
 HYDRAULIC TORQUE ON BUTTERFLY VALVES
 TEST 6

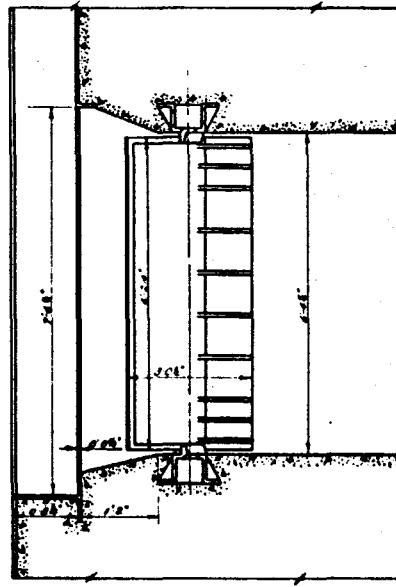
Valves Operating	Valve Opening	Headwater* (ft)	Tailwater* (ft)	Discharge (cfs)	Torque on Valve Trunnions**		
					A (In. Kips)	B (In. Kips)	C (In. Kips)
A, B, C	1/4	34.50	6.5	300	18.4	18.4	24.6
A, B, C	3/8	34.50	6.5	535	21.6	27.8	35.4
A, B, C	1/2	34.50	6.5	756	18.4	30.7	38.3
A, B, C	5/8	34.50	6.5	---	30.7	30.7	24.6
A, B	1/2	23.25	Free	369	12.3	6.1	
A, B	1/2	34.50	6.5	520	27.8	24.6	
A, B	5/8	23.25	Free	551	15.5	15.5	
A, B	5/8	34.50	6.5	682	36.9	36.9	
A, C	5/8	23.25	Free	525	15.5		15.5
A, C	5/8	34.50	6.5	676	18.4		24.6
A, C	3/4	23.25	Free	631	21.6		30.7
A, C	3/4	34.50	6.5	774	30.7		43.0
A	5/8	23.25	Free	254	0.0		
A	5/8	34.50	6.5	340	33.9		
B	1/2	34.50	6.5	286		27.8	
B	5/8	23.25	Free	268		12.3	
B	5/8	34.50	6.5	348		43.0	
B	3/4	23.25	Free	297		27.8	
B	3/4	34.50	6.5	395		49.2	
C	1/4	34.50	6.5	157			24.6
C	1/2	34.50	6.5	306			40.1
C	5/8	23.25	Free	286			24.6
C	5/8	34.50	6.5	377			30.7
C	3/4	23.25	Free	315			18.4
C	3/4	34.50	6.5	431			49.2

*Referred to bottom of culvert at valves.

**Forces tended to close valves.

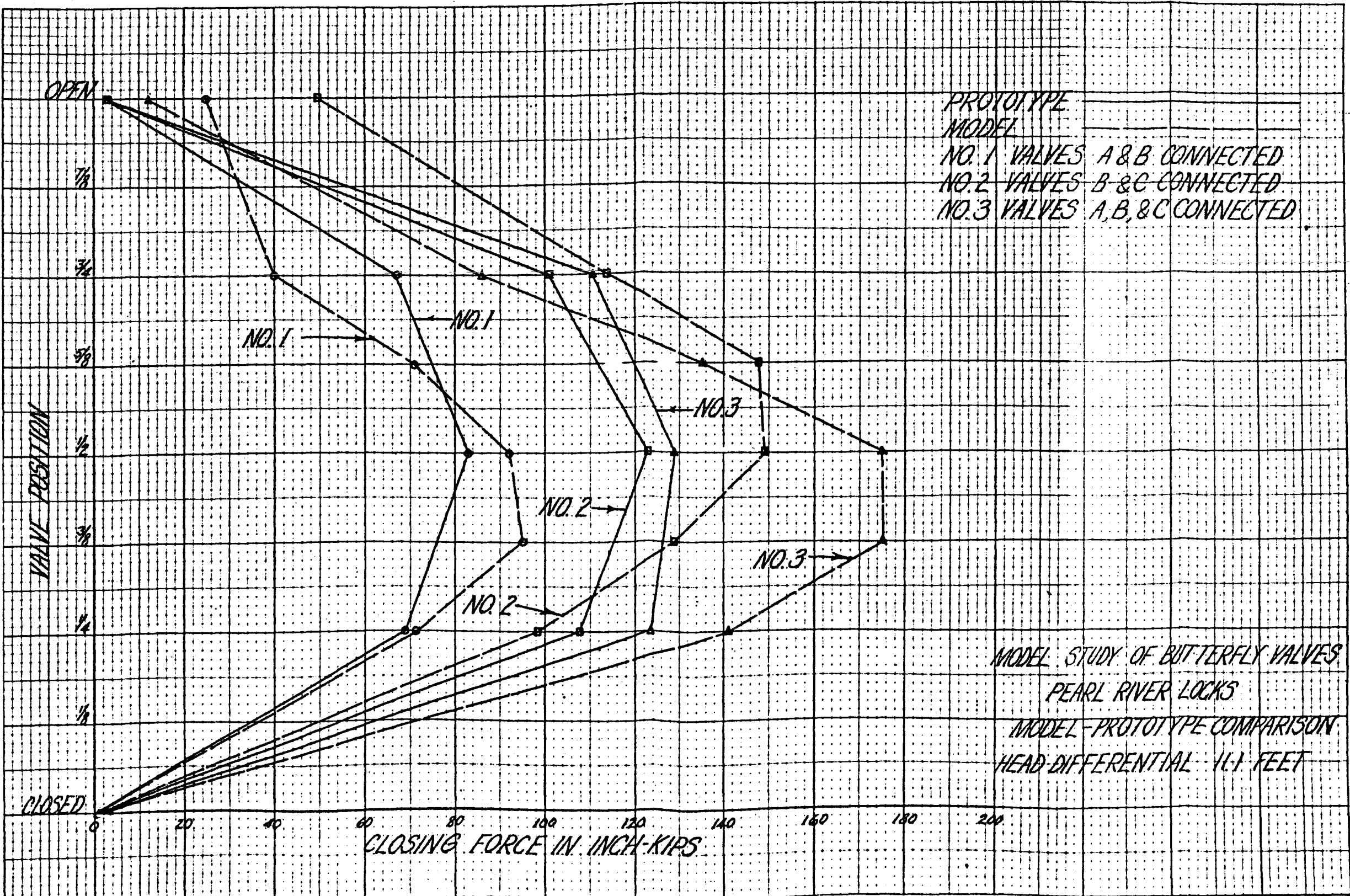


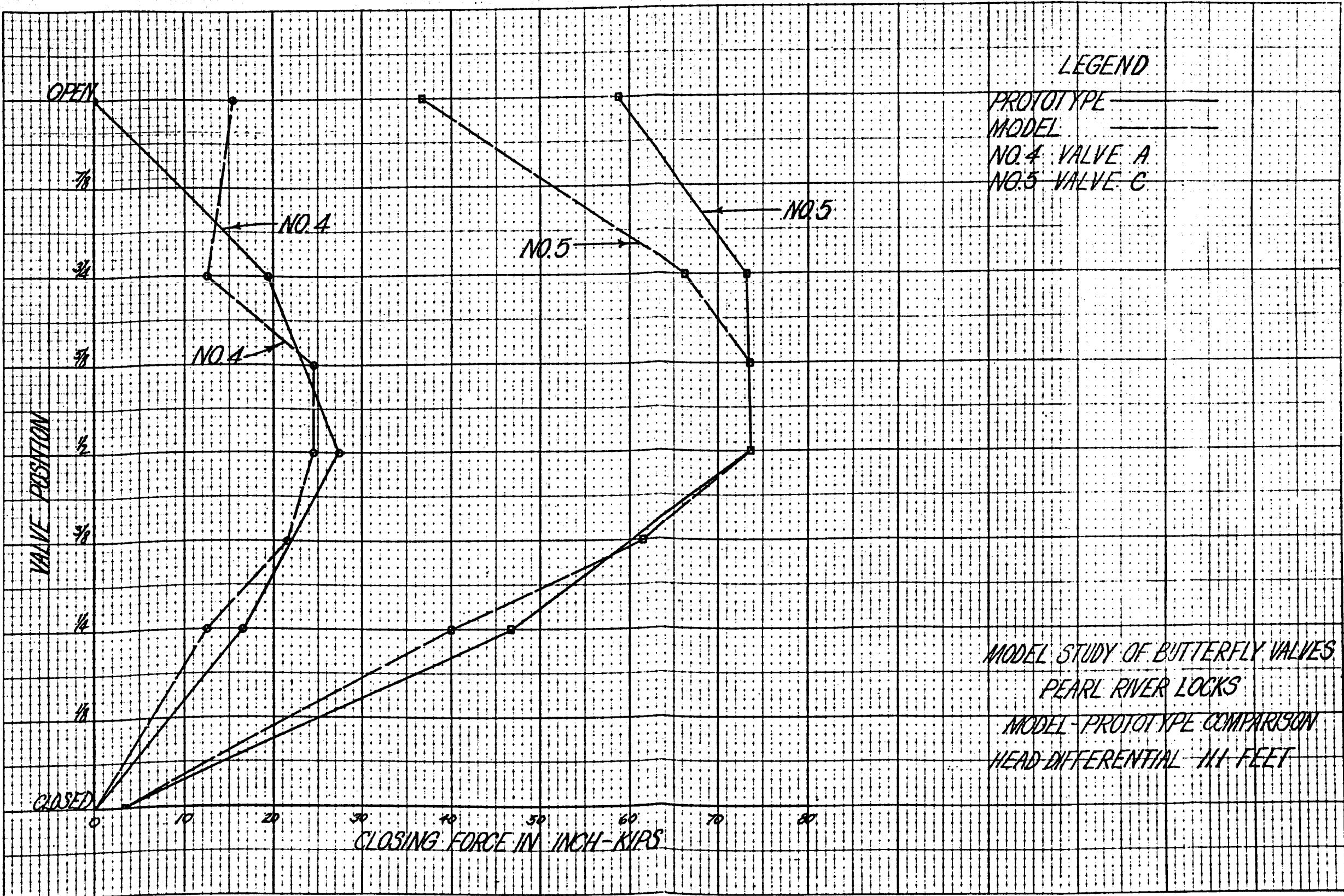
PLAN

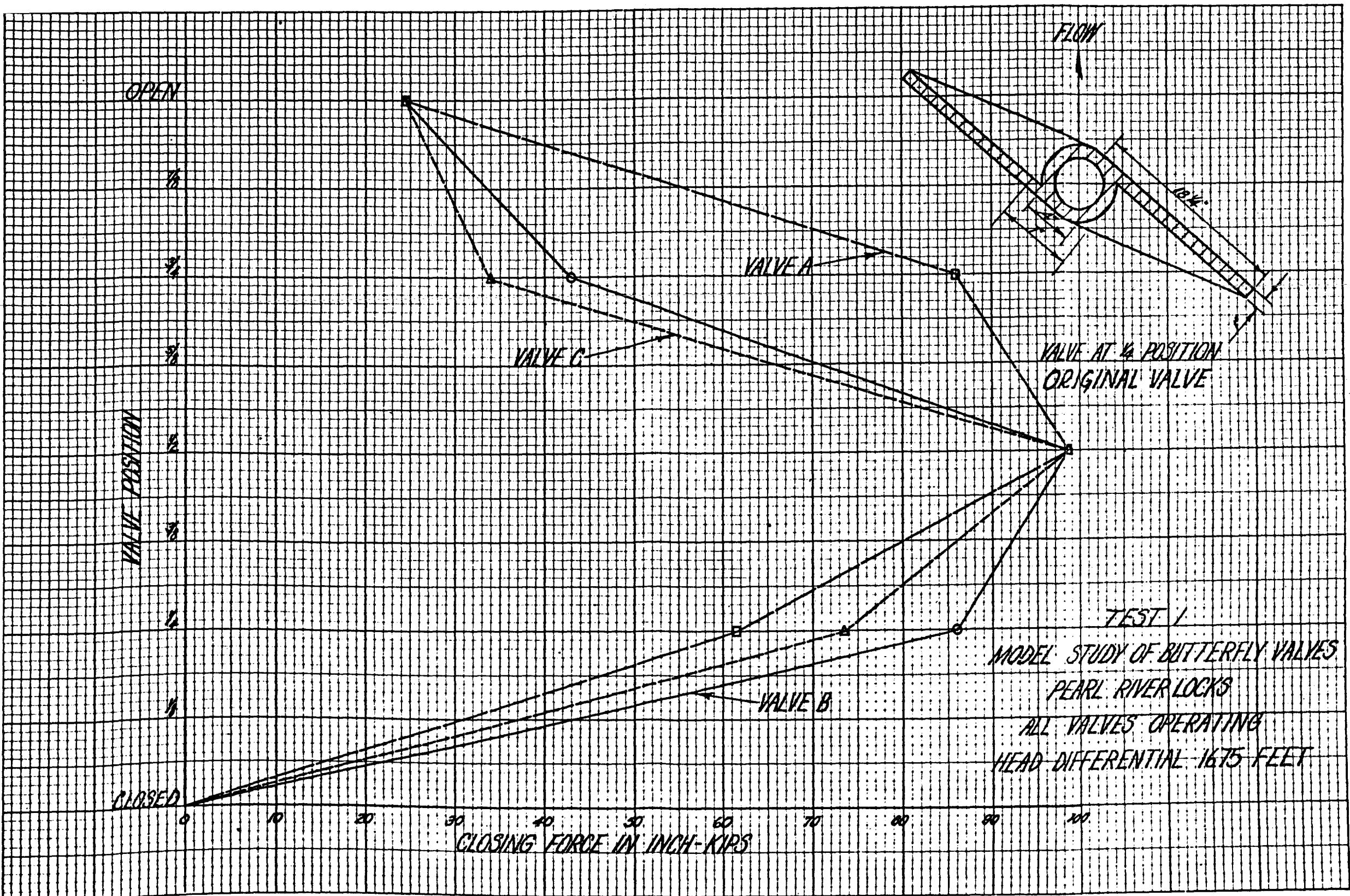


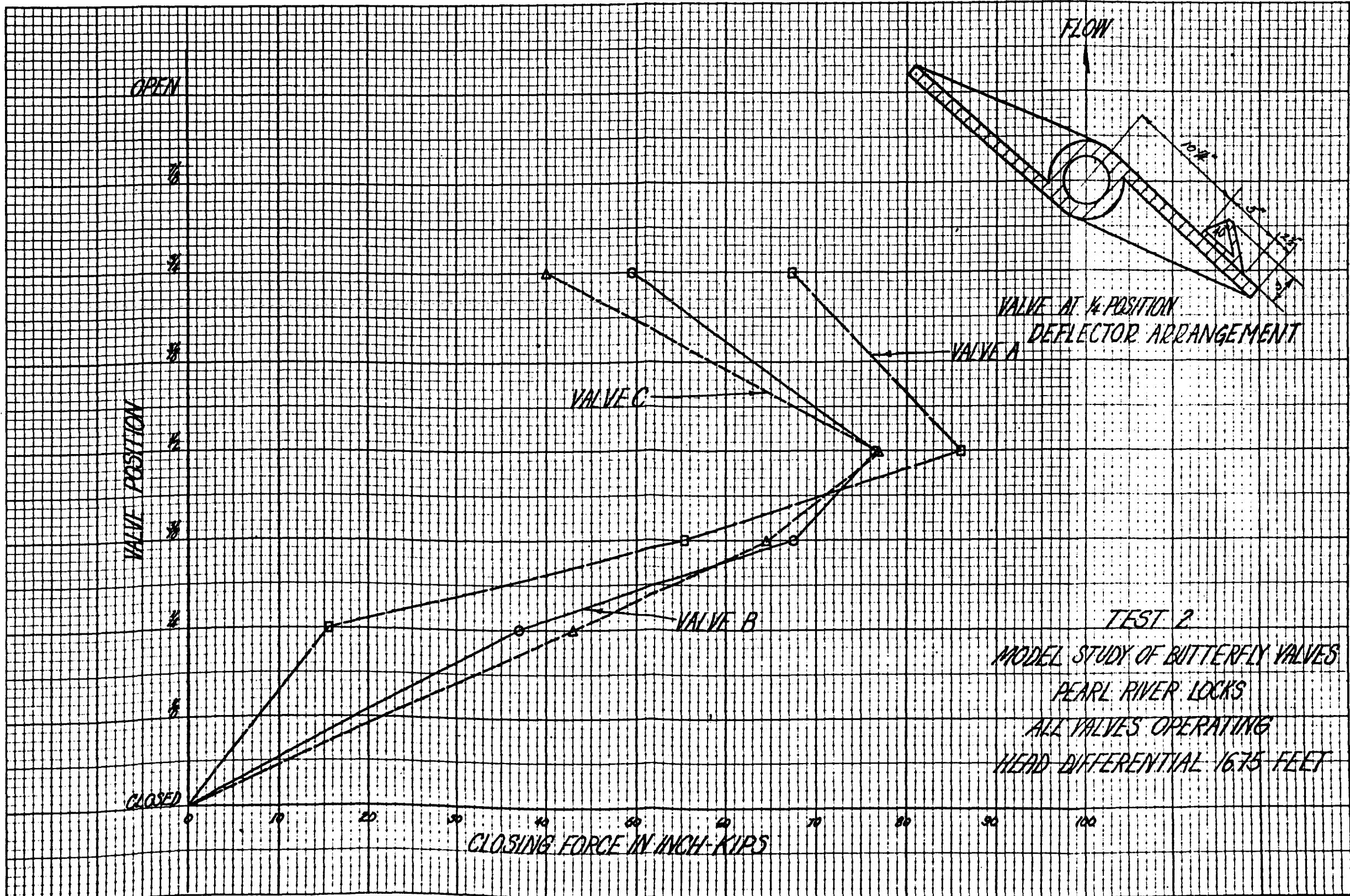
SECTION A-A

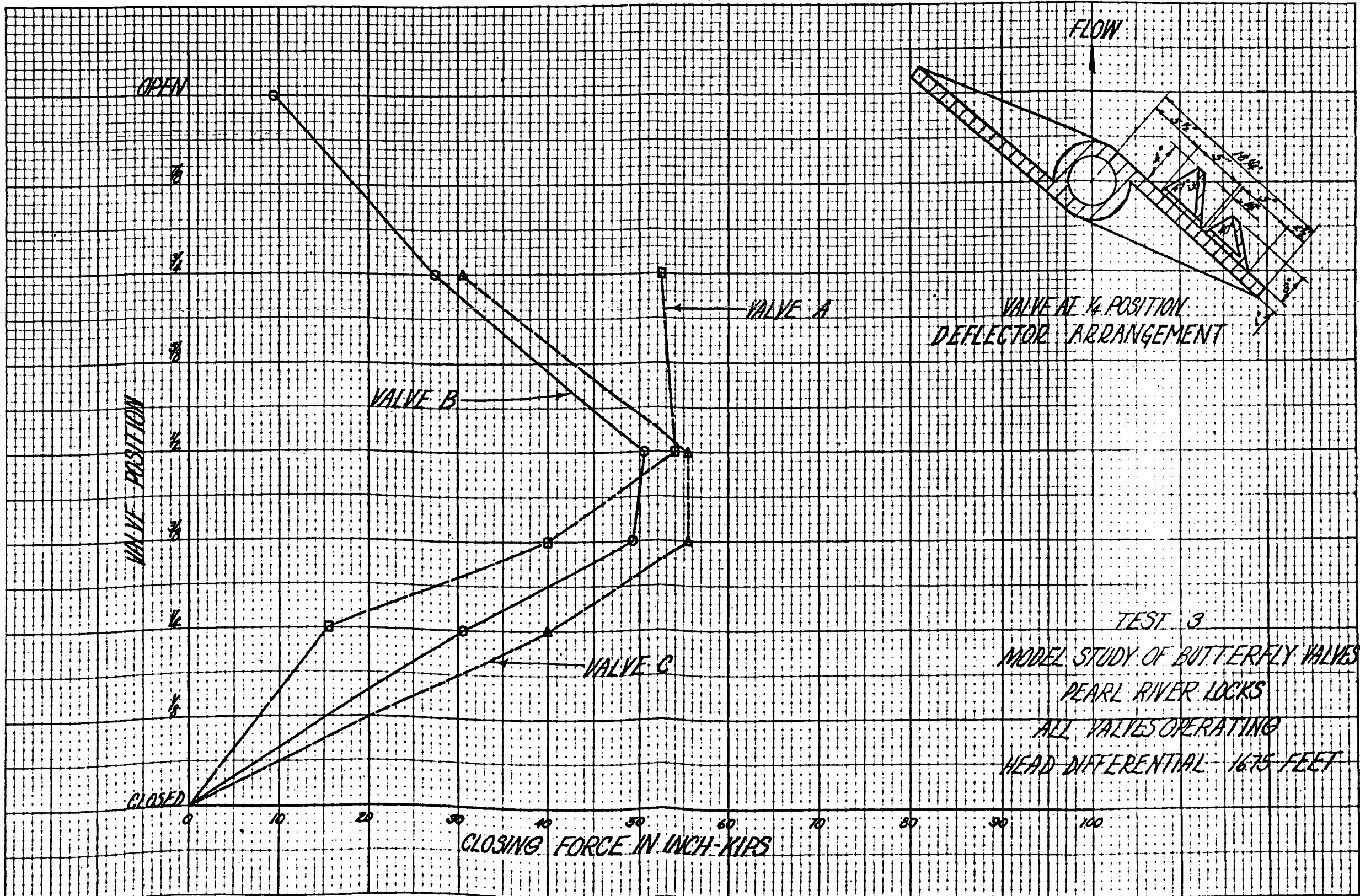
MODEL STUDY OF BUTTERFLY VALVES
PEARL RIVER LOCKS
DETAILS OF CULVERT INTAKE

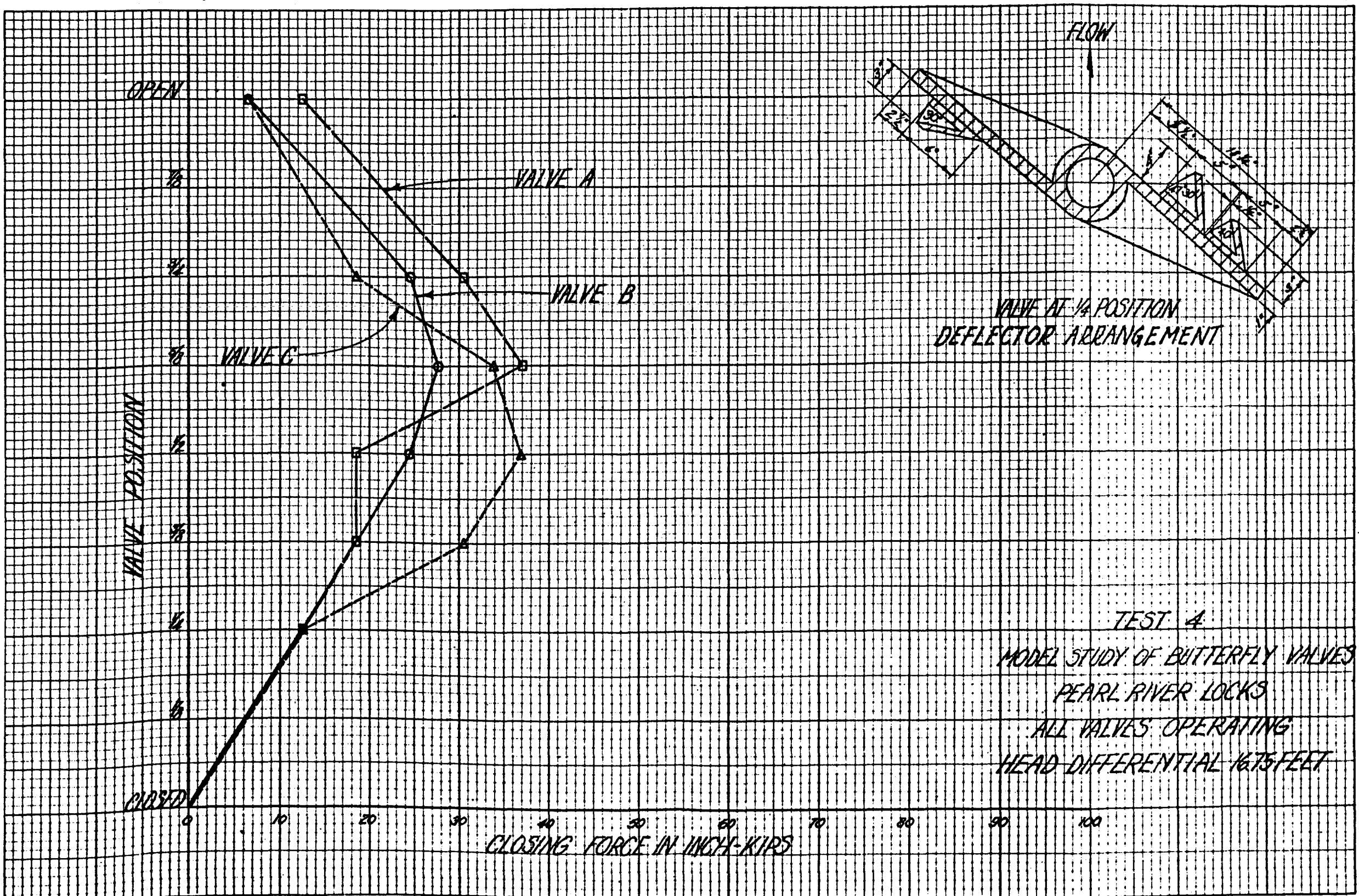


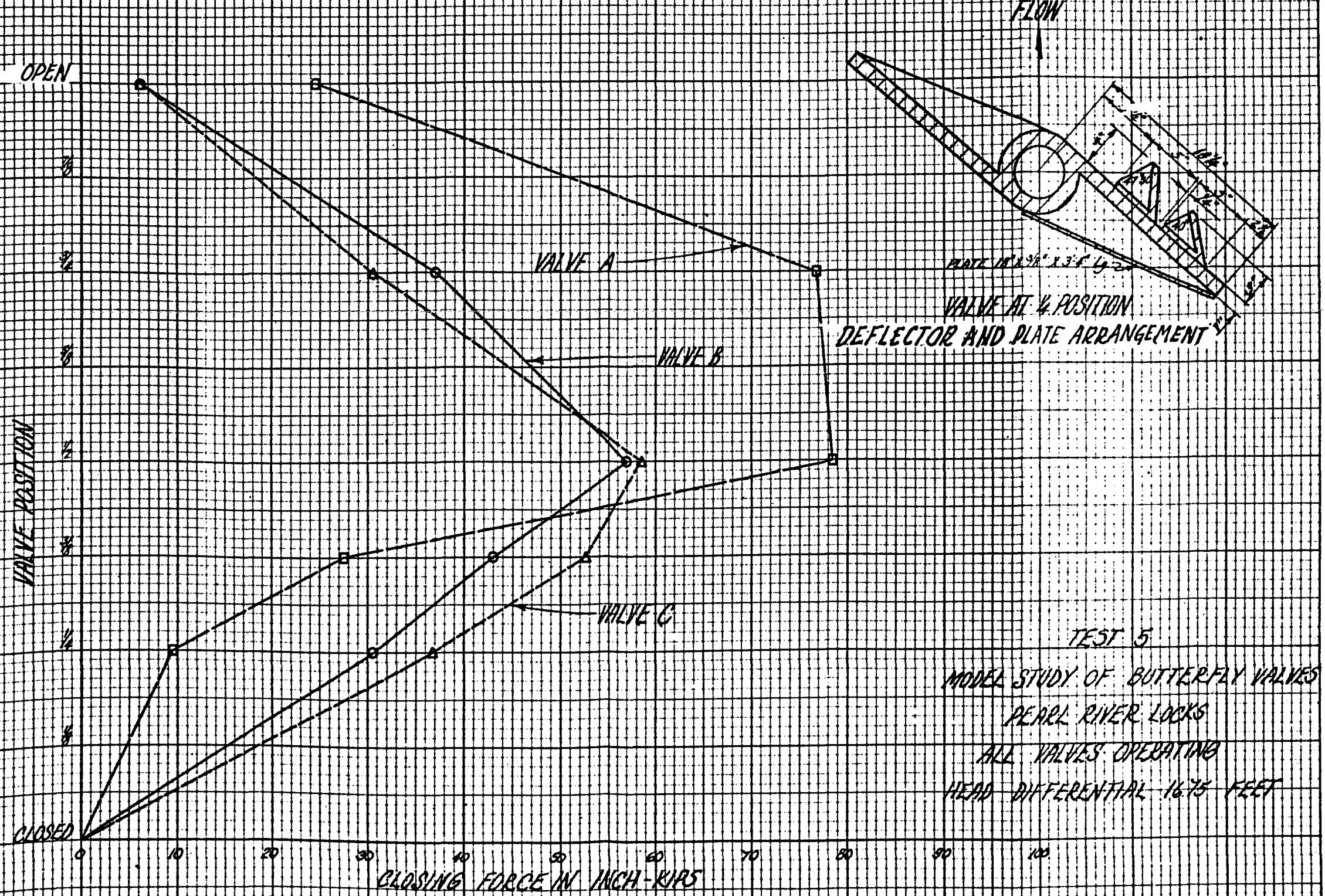






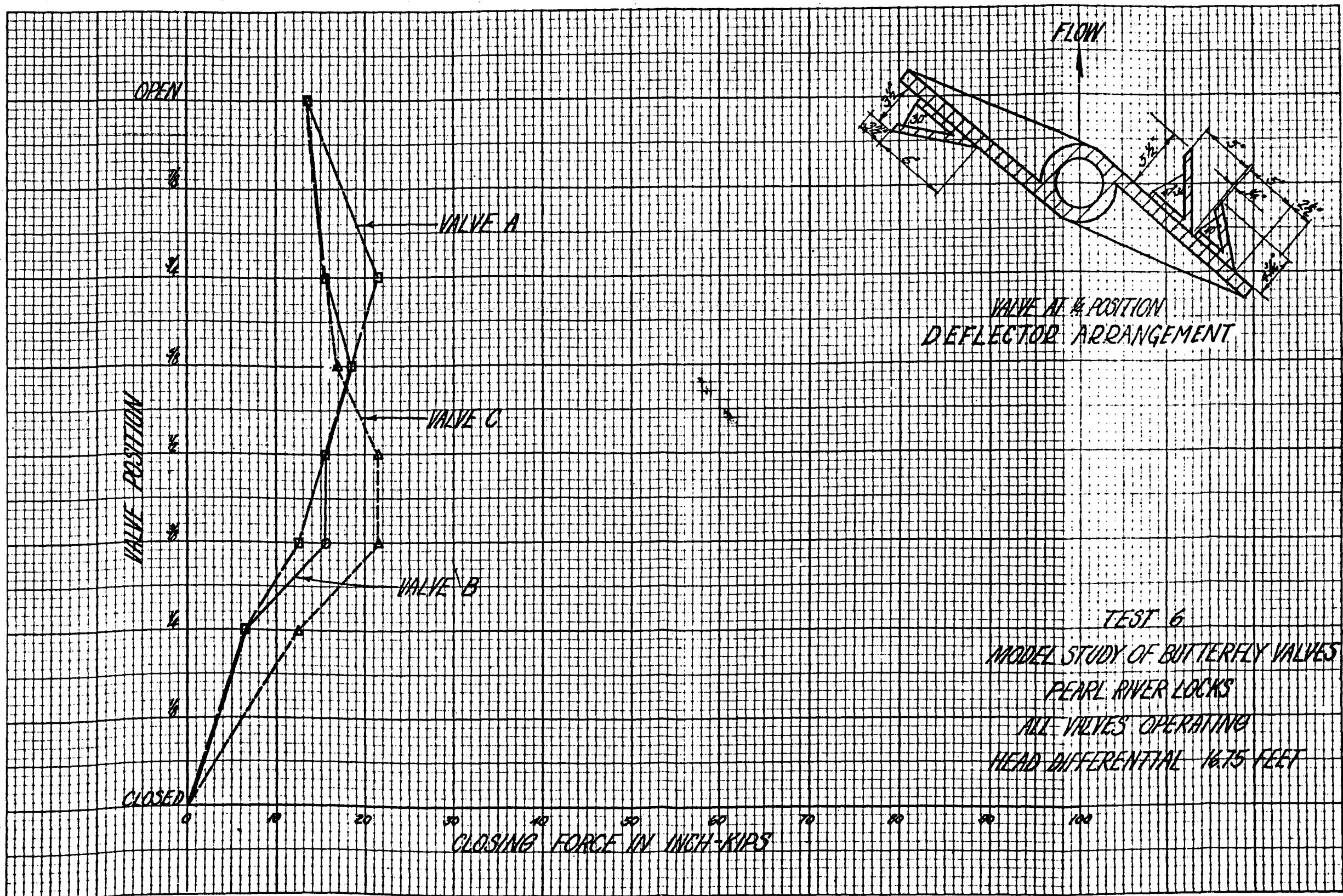






TEST 5

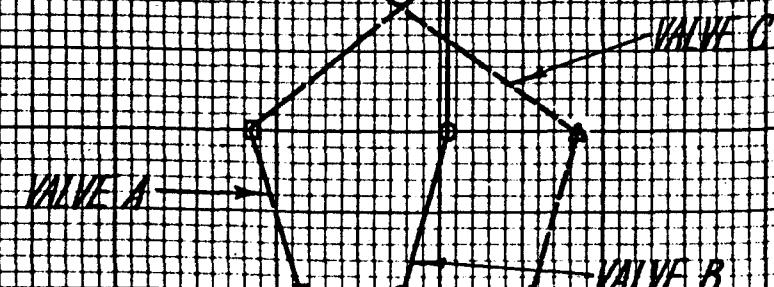
MODEL STUDY OF BUTTERFLY VALVES
 PEARL RIVER LOCKS
 ALL VALVES OPERATING
 HEAD DIFFERENTIAL 16.75 FEET



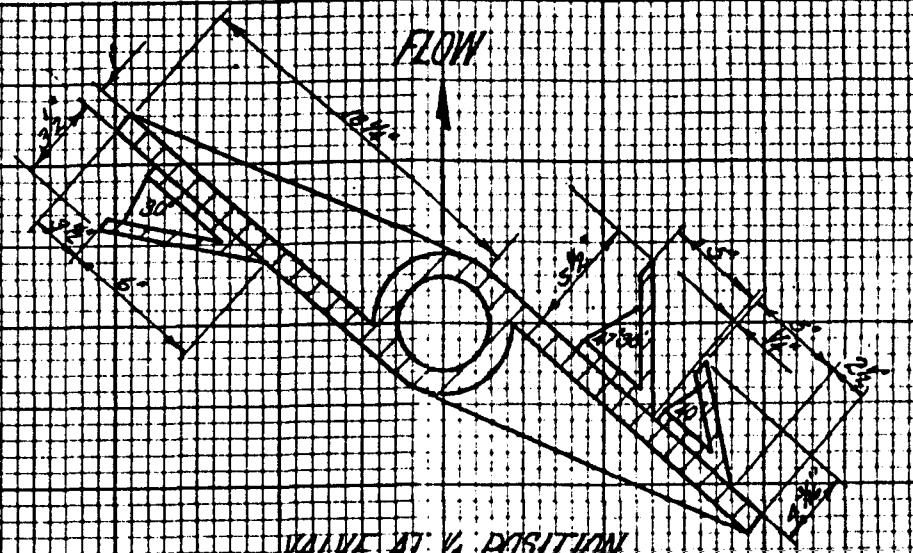
OPEN

VALVE POSITION

CLOSED



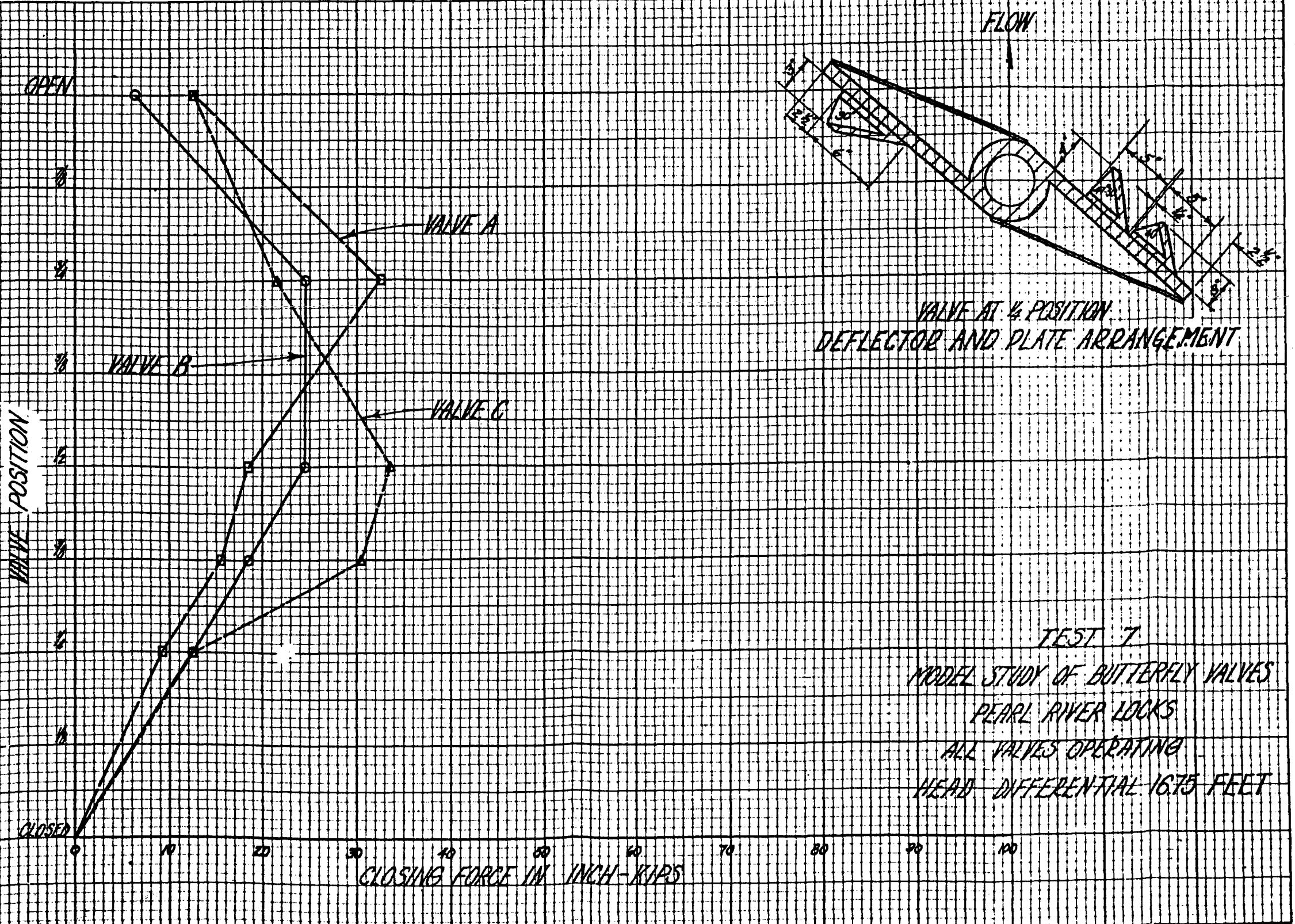
CLOSING FORCE IN INCH-KIPS

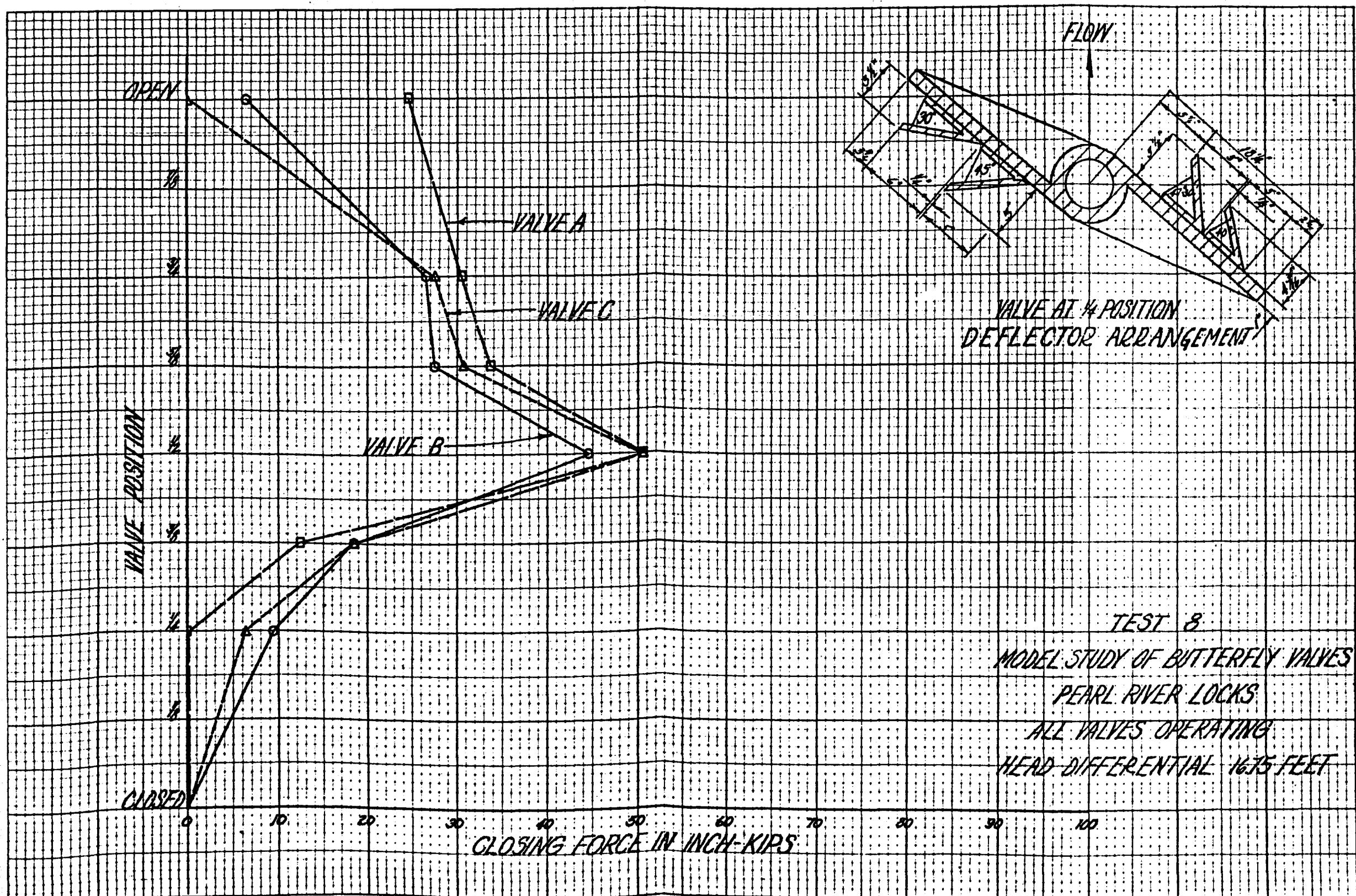


VALVE AT 45° POSITION
DEFLECTOR ARRANGEMENT

TEST 6

MODEL STUDY OF BUTTERFLY VALVES
PEARL RIVER LOCKS
ALL VALVES OPERATING
HEAD DIFFERENTIAL 28.00 FEET





FLOW

VALVE AT 1/4 POSITION
DEFLECTOR ARRANGEMENT

TEST 8

MODEL STUDY OF BUTTERFLY VALVES
PEARL RIVER LOCKS

ALL VALVES OPERATING
HEAD DIFFERENTIAL 16.75 FEET